

MASSIVELY PARALLEL 3-D COUPLED SOLID PROPELLANT ROCKET SIMULATIONS

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The Center for Simulation of Advanced Rockets (CSAR) is an ASCI Level I ASAP center with the primary goal of performing detailed, whole-system, solid propellant rocket simulations based on first principles, rather than on empirical modeling. The GEN2.5 simulation package developed at CSAR is a general-purpose tool for the numerical solution of a wide variety of coupled fluid/structure/combustion problems. GEN2.5 features two explicit finite-volume fluid dynamics solvers, one for structured meshes and one for unstructured; two finite element structural dynamics solvers, one implicit and one explicit; and three ignition and burn rate models. These physics applications exchange interface data frequently across non-matching meshes by means of an algorithm that ensures exact conservation of physical quantities while globally minimizing interpolation errors. Additional services provided by our software framework include a variety of time stepping schemes, parallel I/O, and automatic load balancing through an implementation of the MPI library based on user-level threads that can be moved to another processor with low overhead. Our framework is designed to allow new physics applications to be incorporated with a minimal amount of modification.

We demonstrate that GEN2.5 scales very well up to ~ 1000 processors on an IBM SP, and present results from a suite of verification test problems that exercise various code features. We validate GEN2.5 by comparing numerical results to experimental data involving ignition transients in a small rocket motor, and by computing the larger-than-anticipated propellant deformation in an early Titan IV booster accident scenario. Finally, we follow the motion of a flexible inhibitor, which is attached to the propellant at a joint slot and protrudes into the rocket chamber, and determine its effect on the turbulent flow downstream.



Figure 1. Deformation of the solid propellant at the aft joint slot in the Titan IV SRMU PQM-1 booster.